Ground Source Heat Pumps (GSHP) 101

The theory and application of ground source heat pumps

Mission

The Ground Source Heat Pump (GSHP) RECX serves to enhance the knowledge base of the theory and application of ground source heat pumps throughout USACE. The GSHP RECX also functions to support project development teams from the concept generation phase through the installation phase of their ground source heat pump projects. We also aide in troubleshooting design and installation deficiencies in the ground loop and building loop for ground source heat pump projects.

Services

- Project reviews
- Wellfield design
- GSHP HVAC design
- Ground source service water heating design
- Answer technical questions
- Webinars
- Cost estimating
- GSHP Energy modeling
- LCCA (GSHP only)
- Parametric studies for wellfield design
- Consultation on drilling in potentially contaminated areas
- Assistance in dealing with state regulators
- How to identify substandard grout
- Troubleshooting common subsurface well construction problems

Team Members

- Multidisciplinary group of experts
  - mechanical engineering
  - geology and geotechnical engineering
  - cost engineering
  - electrical engineering
  - project and program management
- 22-member team from across USACE
- Licenses and Certifications
  - 11 Professional Engineers (PEs)
  - 2 Professional Geologists (PGs)
  - 3 Certified Energy Managers (CEM)
  - 1 IGSHPA Certified GeoExchange Designers (CGD)
  - 3 LEED Accredited Professionals (APs)

Sharepoint Site

- Best practices
- Design tools
- Laws and standards
- Training opportunities
- Research
- Articles and case studies
- Discussion board
- Listing of our services
- Located at: http://mrsi.usace.army.mil/sustain/SitePages/CX/HeatPumps.aspx

Projects

- A/E and in-house project reviews
- Design and Construction of Fort Campbell Sustainment Brigade Administration Building
- Design of Joint Base McGuire-Dix-Lakehurst Consolidated Dining Facility
- Webinar: Ground Source Heat Pumps 101
- Parametric study of grout types
- Parametric study of SDR 9 vs. SDR 11 tubing
- Database of in-situ borehole test results, cost estimates, design drawings, etc.

Fort Campbell Sustainment Brigade Complex Administration Building

Ft. Campbell Administration Building

- Under construction
- 30,900 ft^2 facility
- Geothermal wellfield
  - wellfield sized for 100% of building load
  - 69 boreholes each with a depth of 415 feet
  - spacing between boreholes at 20 feet on center
- Airside system
  - air handlers and VAV boxes with hot water reheat served by water-to-water heat pumps
- Anticipate LEED Gold Certification
  - 36.97% energy cost savings from ASHRAE 90.1-2007 baseline
  - 49.68% energy consumption savings from ASHRAE 90.1-2007 baseline without process loads

Joint Base McGuire-Dix-Lakehurst Consolidated Dining Facility (DFAC)

McGuire-Dix-Lakehurst DFAC

- Currently in design
- 30,266 ft^2 facility
- Wellfield with supplemental closed circuit cooler
  - 45 boreholes each with a depth of 400 feet with spacing between boreholes at 20 feet on center and 75-ton CCCT
- Airside system
  - ground source heat pumps
- Designed for a 26% energy cost reduction over an ASHRAE 90.1-2007 baseline building and
- 37% energy consumption reduction over an ASHRAE 90.1-2007 baseline model with process loads removed
- Expected to achieve LEED Silver Certification

GSHP RECX Points of Contact

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GSHP 101 Webinar Learning Objectives

- Understand the nomenclature behind ground source heat pumps
- GSHP applications
- Pros and cons of GSHP
- Understand the difference between air source HPs, water-to-water HPs and water-to-air HPs
- Recognize vertical, horizontal and spiral GSHP configurations
- Learn design considerations for ground heat exchanger design of closed loop systems
- Learn design considerations for water-to-air/water-to-water heat pumps

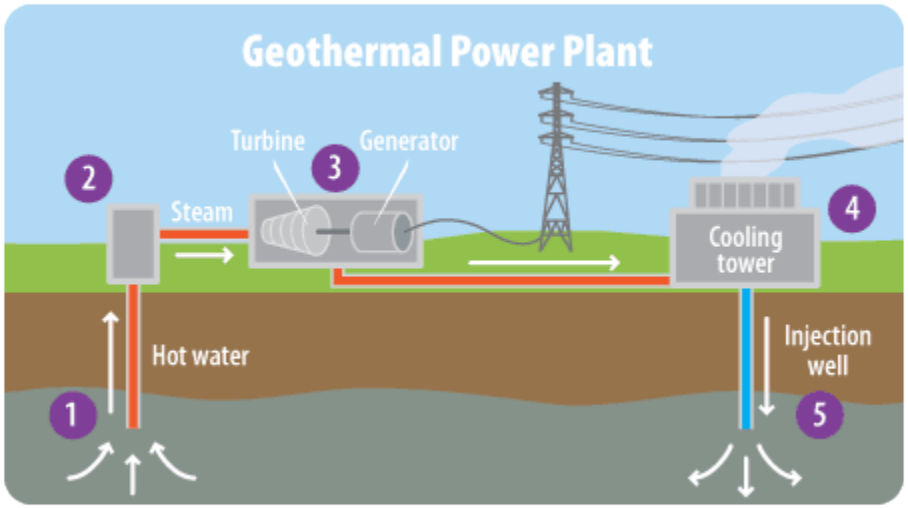
Nomenclature

- Ground source heat pumps
- Geothermal heat pumps
- Ground coupled heat pumps
- Groundwater heat pumps
- Surface water heat pumps
- Ground heat exchanger

“Geothermal” Defined

- The term “geothermal” mistakenly used to describe ground source heat pumps, different from true geothermal energy
- Geothermal energy usually found in the form of hot water or steam geysers or hot springs
- Typically used for electric power generation, space heating, agriculture/aquaculture

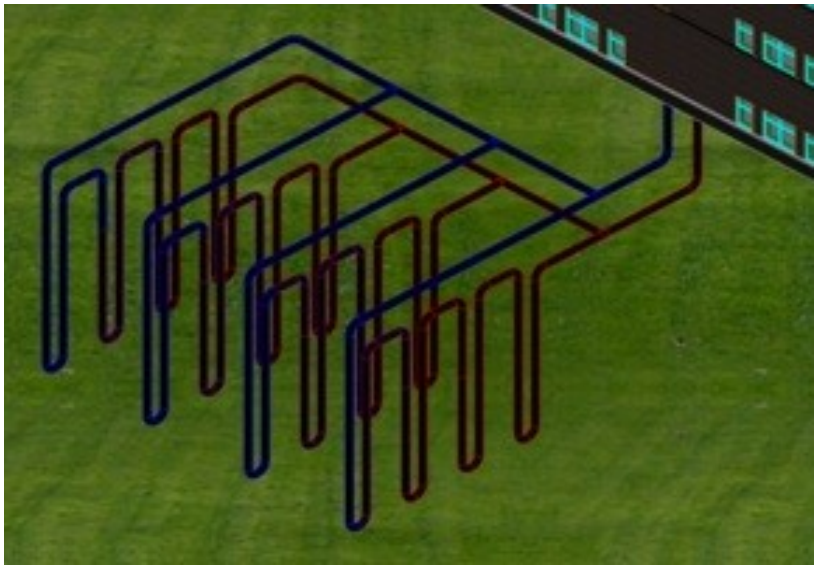
Geothermal Schematic

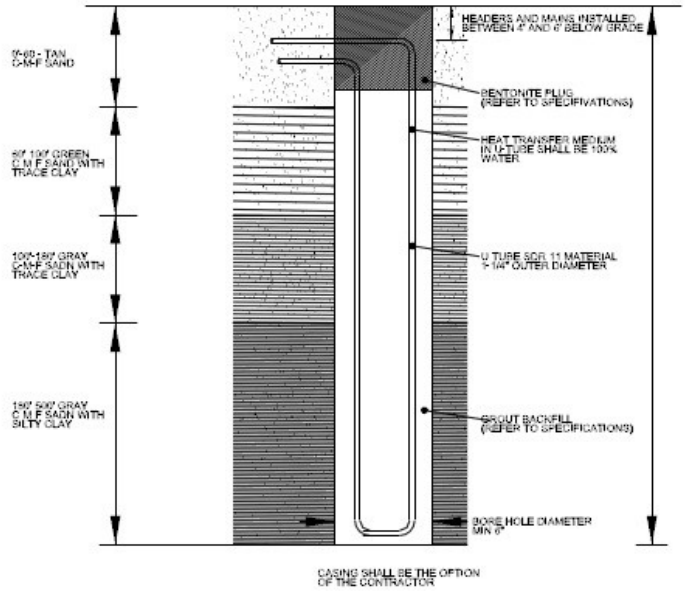


Ground Heat Exchanger Defined

- Underground heat exchanger that can capture heat or dissipate it to the surrounding soil by using the earth’s near constant temperature to warm/cool fluid in underground piping systems
- Refers to the surrounding soil, grout, casings, underground piping, fluid in the piping, underground valves and vaults associated with the piping configuration
- Numerous layouts available

Ground Heat Exchanger Schematic

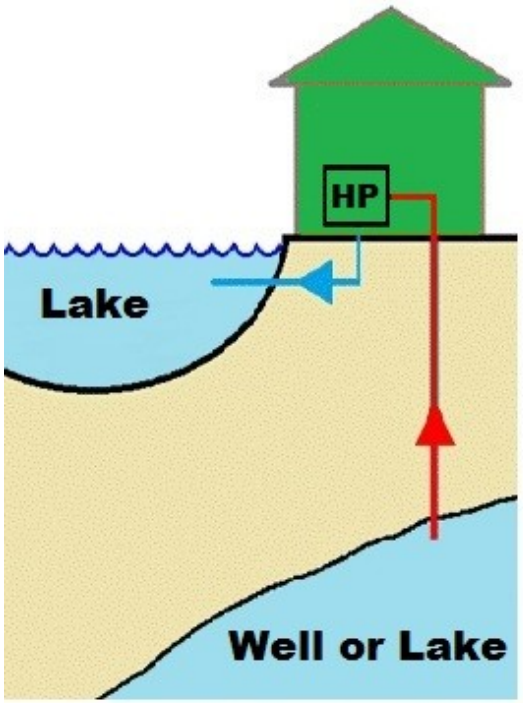



HEADERS AND MAINS INSTALLED BETWEEN 4' AND 6' BELOW GRADE
BENTONITE PLUG (REFER TO SPECIFICATIONS)
HEAT TRANSFER MEDIUM IN U-TUBE SHALL BE 100% WATER
U TUBE SDR 11 MATERIAL 1 1/4" OUTER DIAMETER
GROUT BACKFILL (REFER TO SPECIFICATIONS)
BORE HOLE DIAMETER MIN 6"
CASING SHALL BE THE OPTION OF THE CONTRACTOR

Groundwater Heat Pumps Defined

- Subset group of ground source heat pumps
- Consists of a water-to-water heat exchanger connected between groundwater source (usually a well, lake or large body of water) and water-to-air heat pumps
- Must be careful about corrosion and fouling when designing systems using untreated groundwater
- Local environmental regulations may preclude the use of injection of groundwater
- Commonly referred to as a “pump and dump” system

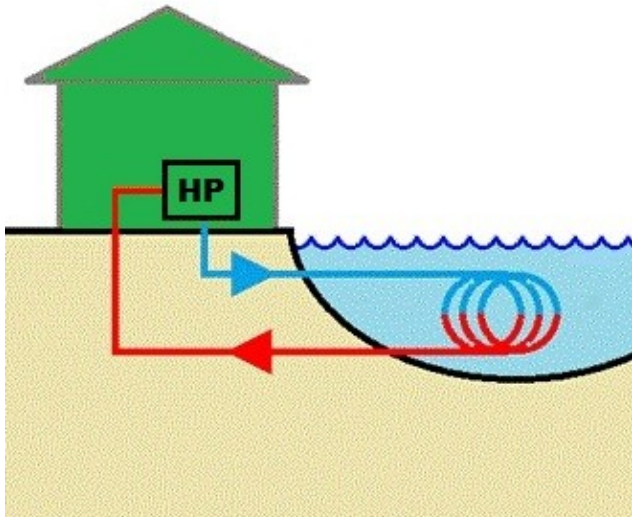
Groundwater Heat Pump System Schematic



Surface Water Heat Pumps Defined

- Subset group of ground source heat pumps
- Large body of water used as a heat sink/heat source
- Can be open loop or closed loop
- Closed loop systems consist of a water-to-water or water-to-air heat pumps connected to piping in a lake, river or other large body of water
- Open loop systems consist of surface water directly pumped through water-to-air heat pumps or through a water-to-water heat exchanger and then pumped back into the surface water body
  - Corrosion and fouling can be significant issues in open loop systems

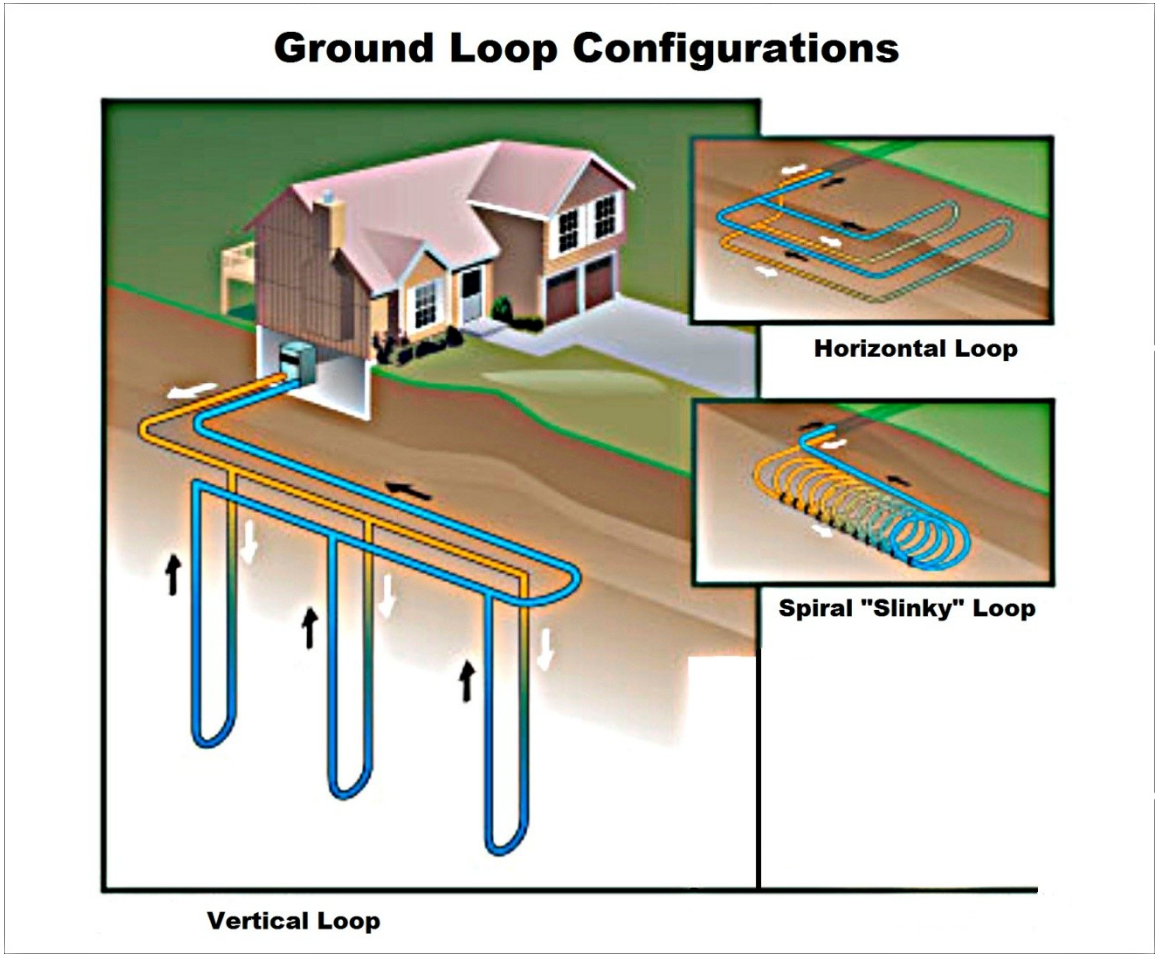
Surface Water Heat Pumps Schematic



Ground Coupled Heat Pumps Defined

- Subset group of ground source heat pumps
- Usually refer to a closed loop ground source heat pump system
- Consists of a reversible vapor compression cycle heat pump and a closed ground heat exchanger buried in the soil
- Three common ground heat exchanger design layouts
- Fluid medium usually water or ethylene glycol solution
- Most common type of ground source heat pump system used
- Focus of this presentation

Ground Coupled Heat Pumps Schematic



Ground Source Heat Pump Applications

- Common uses include service water heating and providing heating, cooling and ventilation for indoor conditioned spaces
- Types:
  - Groundwater heat pumps
  - Surface water heat pumps
  - Ground coupled heat pumps (focus of this presentation)
- Consist of ground heat exchanger and above ground mechanical system (water-to-air heat pumps, water-to-water heat pumps, building and/or ground pumps, expansion tank, air separator, valving, desuperheater, piping)

Pros

- Uses the ground as a heat exchanger, full GSHP systems do not require the addition of plant equipment such as boilers and cooling towers unless a hybrid system is used
- Less maintenance
- HDPE piping used for wellfield typically has a warranty of 50 years, most convenient plant equipment is anticipated to last 15-25 years
- Typically more energy efficient than most HVAC systems

Cons

- Typically higher first cost due to cost of drilling
- Site conditions may constraint or limit the design of the ground heat exchanger
- In-situ testing prior to design is recommended
- Lack of general understanding of ground heat exchanger and heat pump operation
- Compliance with local environment regulations

Types of Heat Pumps

- Air to Air
- Water to Water
- Water to Air
  - Water Source
  - Ground Source

Air-to-Air Heat Pumps

- Not used in ground source heat pump applications
- Dedicated outdoor air systems (DOAS) not always required
- Commercial and residential applications
  - Most heat pumps seen in homes are air-to-air heat pumps
- Heat is extracted from the outdoor air during the heating mode
- Heat is rejected to the outdoor air during the cooling mode

Water-to-Water Heat Pumps

- Domestic hot water (service water) as a desuper heater
- Provides Hot and chilled water for 2-pipe and 4-pipe systems
- Two water coils, one for source side and one for load side
- Heat is extracted from the source side and added to the load side water coils during heating
- Heat is rejected to the source side and extracted from the load side water coil during cooling

Water Source Heat Pumps

- Heat is rejected from the water coils to a cooling tower
- Heat is added to the water coils from a boiler
- Dedicated outdoor air system (DOAS) recommended to precondition outdoor in most applications
- Conventional design

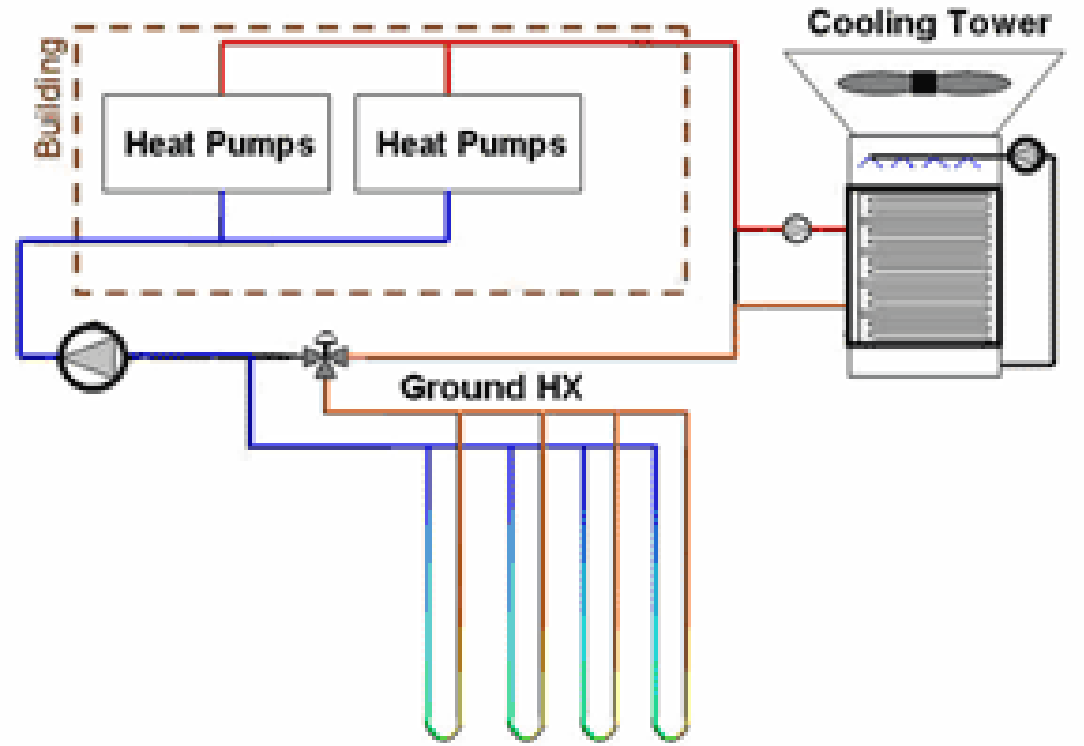
Full Ground Source Heat Pumps

- Water coils receive heated/cooled water from the ground heat exchanger with the ground heat exchanger as the sole form of heat addition/rejection
- Dedicated outdoor air system (DOAS) recommended to precondition outdoor air in most applications
- Less costly to maintain, usually only ground loop pumps and/or building loop pumps and indoor heat pumps need to be maintained
- Energy efficient HVAC solution
- Higher first cost due the ground heat exchanger
- A cost/benefit analysis (energy savings, first cost, ongoing maintenance of additional equipment) is recommended to determine if a full ground source system or hybrid ground source system is right for the facility

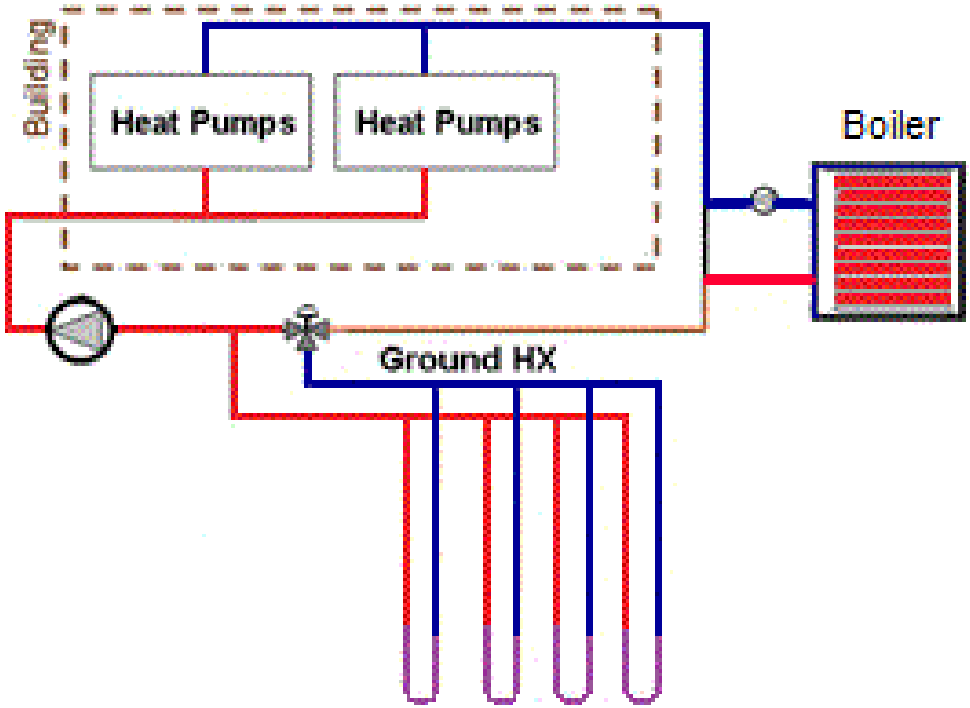
Hybrid Ground Source Heat Pumps

- Water coils receive heated/cooled water from the ground heat exchanger
- Supplemental provided by a cooling tower to reject heat to the outdoor air
- Supplemental heating provided by a hot water boiler to directly add heat into the loop
- Can have either a cooling tower or a boiler or both
- Dedicated outdoor air system (DOAS) recommended to precondition outdoor air in most applications
- Less energy efficient
- Reduced first cost
- More maintenance required

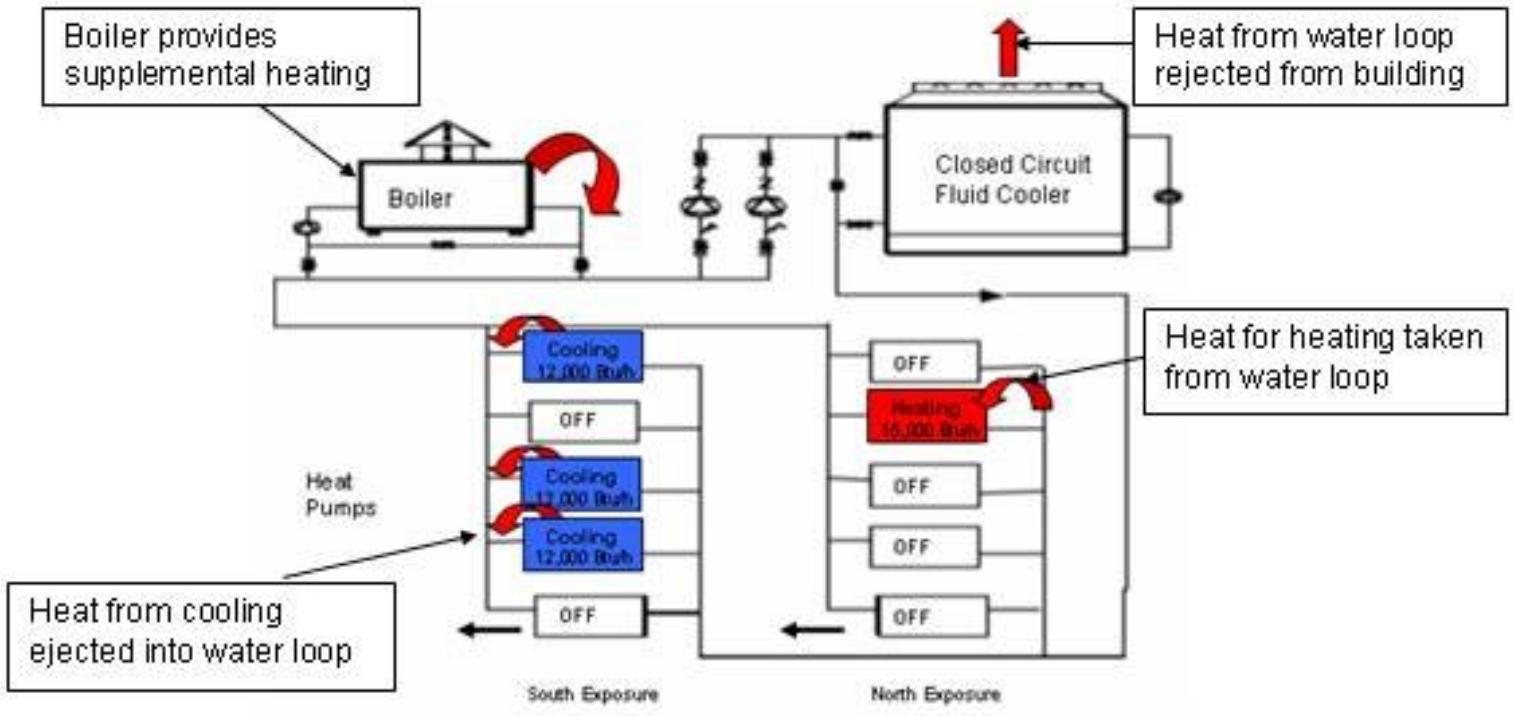
Hybrid GSHP System - Cooling Tower



Hybrid GSHP System - Boiler

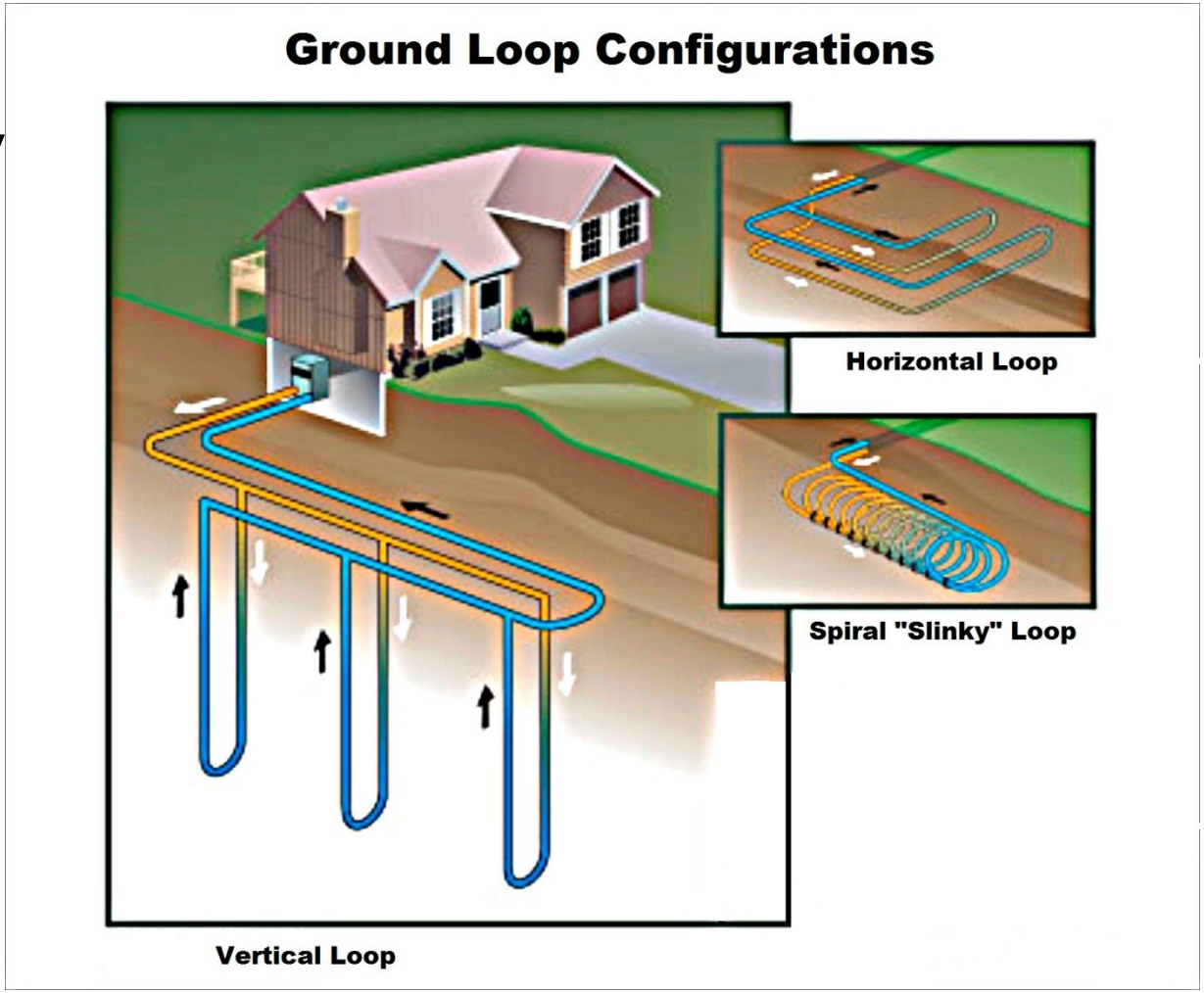


Hybrid GSHP System - Boiler, Cooling Tower



Closed Loop Ground Heat Exchangers

- Vertical
- Horizontal
- Spiral “slinky



Closed Loop Vertical Heat Exchanger

- Soil temperature is stable in deep wells
- Typical well depth is between 150 – 500 feet
- Smaller land requirement than other configurations
- Highly adaptable to most sites
- Geological conditions must be favorable
- High drilling cost
- Requires experienced well driller
  - Recommend IGSHPA certified installer
- Recommend in-situ testing be performed prior to design
- Most common configuration for ground coupled heat pumps

Closed Loop Horizontal Heat Exchanger

- Soil temperature can vary seasonally, design must account for large temperature swings
- Temperature swings can adversely impact performance
- Lower efficiency than vertical heat exchangers
- Largest land requirement
- Less adaptable to most sites
- Less expensive to install
- Appropriate equipment and trained contractors widely available
- Installed in trenches at least 4 feet deep
- Layouts can include single pipe, 2 pipe or 4 pipe configurations

Closed Loop Slinky Heat Exchanger

- High soil temperature variability with seasons, temperature swings can impact performance
- Lowest efficiency of all closed loop horiztonal heat exchangers
- Large land requirement
- Type of closed loop horizontal heat exchanger
- Less adaptable to most sites
- Less expensive to install
- Appropriate equipment and trained contractors widely available
- More piping installed per square foot
- Coiled piping design to reduce horizontal area needed for heat exchanger

Design Considerations – GHX

- Site constraints including in-situ test results
- Energy efficient requirements, first cost limitations, life cycle cost analysis
- Building load profile (heating or cooling dominated)
- Full GSHP or hybrid GSHP
- Potential to share ground heat exchanger between multiple buildings
- Fluid medium in the piping
- Piping layout (reverse or direct return)
- Type of HDPE piping (usually SDR 9 or 11)

Design Considerations – GHX Cont.

- Spacing between boreholes/loops
- Number of boreholes/loops
- Optimal vertical borehole or horizontal loop depth
- Diameter of borehole
- Number U-tubes in borehole or loops/coils in trench
- Pipe diameter
- Grout type
- Analysis period (25 years typical)
- Ground heat exchanger temperature creep over time
- Software constraints
- Pumping requirements
- Pump control (constant or variable speed)

Design Considerations – Heat Pumps

- Distributed design versus centralized design
- Pretreatment of outdoor air
- Service water heating
- Type of heat pumps required (WWHP, WAHP)
- Water-to-water heat pump source side and load side control considerations
- Capacity to overcome night setback/setup
- Zoning
- Maintenance
- Refrigerant
- Vibration isolation
- Energy efficiency (standard vs. high efficiency)

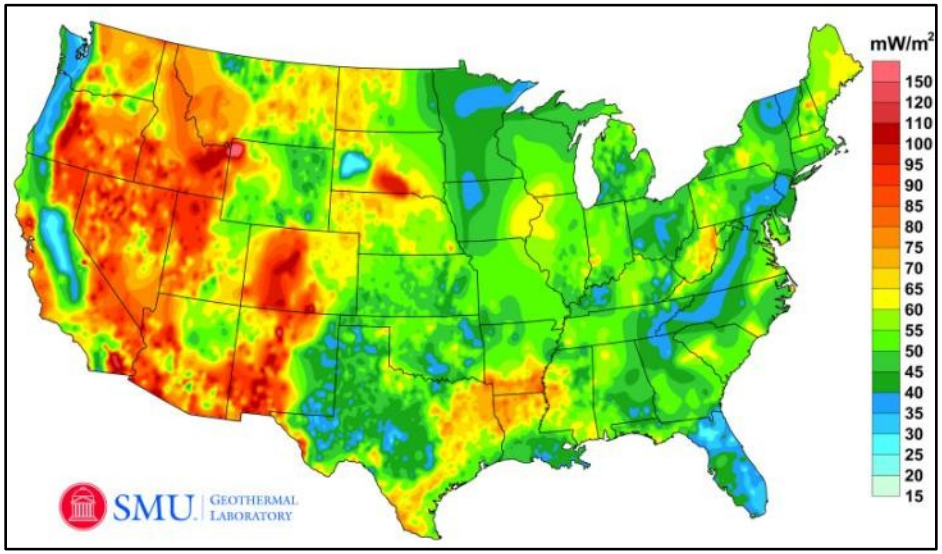
Design Considerations – Heat Pumps Cont.

- Heat pump loop temperature range requirements (standard versus extended range)
- Fan control (constant, two speed, variable speed)
- Compressor operation (single, dual, staged, variable capacity)
- Fluid medium
- Piping layout (reverse or direct return)
- Pumping requirements
- Pump control (constant or variable speed)
- Air separator and/or expansion tank
- Boiler and/or cooling tower is used

Examples

- Numerous DoD installations
- Environmental Protection Agency
- Bureau of Indian Affairs
- Veteran’s Affairs
- U.S. Postal Service
- Housing and Urban Development
- Types of facilities served include office buildings, housing, medical facilities, schools, training facilities, communications facilities, court houses

Where do ground source heat pumps work?



Questions